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HUMAN RESOURCES

STRESS AND SIMULATION IN PILOT TRAINING

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Catecholamine excretion for 20 USAF student pilots and 13 instructor pilots was determined during daily activities, during sorties performed in high realism simulators, and during actual flight. High realism simulation resulted in a measurable stress response in both students and instructors; the response was not related to previous flight experience. One group of students (experimental, n=10) experienced power-on stalls and spin recoveries in the simulator prior to their introduction in the aircraft. A second group of students (control, n–10) experienced power-on stalls and spin recoveries in the aircraft prior to their introduction in the simulator. Catecholamine excretion during simulation was not different for the two groups, thus aircraft exposure to the spin series did not alter the stress response of the students attemping a similar maneuver in a high realism simulator. Catecholamine

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CONT

excretion during the aircraft spin was also similar for the experimental and control groups; however, the relative proportions of epinephrine and norepinephrine were different for the experimental and control groups. Thus, task-specific high realism simulation introduced prior to exposure to related stressful in-flight tasks results in similar total stress response, but somewhat lower arousal and greater mental activity. A comparison of superior and inferior students within each group suggested that the simulator pretraining had the greatest effect on the inferior students. A comparison of student and instructor catecholamine excretion from the aircraft power-on stall and spin recovery lesson unit showed a lack of significant relationship. There was, however, a significant negative relationship between student performance and instructor stress during the initial aircraft power-on stall and spin recovery sortie.

PREFACE

This research was conducted by the Human Performance Laboratory; Department of Health, Physical Education and Dance; Arizona State University under provisions of Contract F41609-75-C-0028. The work unit was part of project 2313, Human Resources; task 2313-T5 Information Processing and Cognitive Components of the Flying Task; Herbert J. Clark project scientist and Gary B. Reid contract monitor.

Special thanks are extended to Dr Joe DeMaio and Airman Randy Cline for their assistance in the conduct of this study. Appreciation is also extended to Mrs Marla Lawrence for her help in preparation of this manuscript.

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Introduction

Selected aircraft lesson units of T-37 pilot training have been shown to be extremely stressful to student pilots. When performed in a simulator, learning experiences appear to be much less stressful. Since stress plays an important role in human sensing, perception, and learning, the influence of high realism simulation on the airborne physiological stress responses of student pilots was investigated.

Rationale

Moderate levels of stress appear to accompany the most effective learning, therefore, it would seem that training procedures which could restore stress within acceptable limits would be beneficial in pilot training. The assessment of neuroendocrine responses holds potential for greater understanding of the stress-learning milieu of flight training.

Objectives

The present investigation was designed to provide information about five specific questions raised by previous research.

(1) Does high realism simulation result in a measurable stress response?

(2) Does previous airborne flight experience alter one's stress response during simulated flight in the advanced simulator for pilot training?

(3) Does task-specific high realism simulation prior to exposure to a stressful in-flight lesson unit influence stress and/or learning in the T-37 aircraft?

(4) Does task-specific high realism simulation prior to exposure to high stress airborne sorties differentially influence T-37 stress of superior and inferior student pilots within the successful range?

(5) Is there a relationship between student and instructor pilot stress during high-stress lesson units in the aircraft?

Methodology

The subjects were USAF T-37 pilot training students and instructor pilots. In addition to T-37 syllabus requirements, the student subjects participated in four orientation rides and two power-on stall and spin

recovery rides in the advanced simulator for pilot training. In addition to their flight-line instruction duties, the instructor pilots participated in two sorties performed in the advanced simulator for pilot training.

Stress was measured by determining the amount of catecholamine (epinephrine plus norepinephrine)* excreted into subjects' urine. The relationship between catecholamines and stress has been the object of considerable research. In general, epinephrine seems to be associated with a state of general arousal whereas norepinephrine may be related to mechanisms concerned with mental work.

Excretion data were gathered on two non-flying days to provide individual baselines. Urine collections were also made after all simulator sorties and the corresponding aircraft sortie.

Results

(1) High realism simulation resulted in a measurable stress response in both students and instructors; the response was not related to previous flight experience. One group of students (experimental) experienced power-on stalls and spin recoveries in the simulator prior to their introduction in the aircraft. A second group of students (control) experienced power-on stalls and spin recoveries in the aircraft prior to their introduction in the simulator. Catecholamine excretion during simulation was not different for the two groups, thus aircraft exposure to the spin series did not alter the stress response of the students attempting a similar maneuver in a high realism simulator.

(2) Catecholamine excretion during the aircraft spin was also similar for the experimental and control groups; however, the relative proportions of epinephrine and norepinephrine were different. Thus, task specific high realism simulation introduced prior to exposure to related stressful inflight tasks results in similar total stress response, but somewhat lower arousal and greater mental activity. In other words, students who have had simulator training prior to the aircraft mission display less apprehension and accomplish more mental work than do students who have not had the simulator.

(3) A comparison of superior and inferior students within each group suggested that the simulator pretraining has the greatest effect on the inferior students.

(4) There was no correlation between students' and instructors' catecholamine excretion levels. The stress level of one of the pair (IP

*Also known as adrenalin and noradrenalin

and student) did not seem to affect the stress level of the other member of the pair.

(5) There was, however, a significant negative relationship between student performance and instructor stress during the initial aircraft power-on stall and spin recovery sortie. This relationship may indicate one of at least three things: (a) poor student performance causes an increase in the stress level of the instructor pilot, (b) an instructor is more likely to give a student a poor grade when the instructor is under a high level of stress, or (c) a combination of both a & b.

Implications

While simulation training has become widely accepted, it is commonly thought that because of the secure environment of the simulator that this type of training lacks the "pucker factor" and therefore degrades the value of the training. The results of this research suggest that, contrary to popular opinion, a simulator as well as an aircraft can invoke a stress response when both devices are used to present the same mission scenario. Additionally, this training can alter the stress response during subsequent aircraft training. The altered response indicates that extra simulator rides for average or below average students should improve their actual aircraft performance. These results indicate that this improvement is a result of an alteration of the students' stress level as well as motor skill practice.

II. BACKGROUND

The study of stress holds potential significance for pilot training because stress plays an important role in human sensing, perception and learning (Mathis, 1967). Moderate levels of stress improve learning (Levine, 1971); however, high levels of stress result in behavioral rigidity which increases the time required to attain competence on a new task (Eysenck, 1976). In a recent experiment by Krahenbuhl, et al. (1977), it was demonstrated that selected lesson units of T-37 pilot training were extremely stressful to student pilots. The same investigation also suggested that flight training lesson units performed in an instrument flight trainer (low fidelity simulator) were no more stressful than daily activities, even though the lesson unit involved emergency procedures and was expected to be somewhat stressful.

Moderate stress should theoretically provide the optimal level of alertness for learning and safety. Since various elements of T-37 pilot training were characterized by either extremely low arousal, in the case of simulation, or by extremely high arousal, in the case of the aircraft power-on stall and spin recovery lesson unit, it seemed appropriate to direct further study toward undergraduate pilot training stress-learning interaction.

This approach may also provide useful insights regarding simulator realism. With the growing concern over petroleum supply, more flying training tasks are being relegated to simulation. The investigation of physiological responses to simulated flying and the influence of high realism simulation on the airborne physiological responses of student pilots are areas of study which have received little research attention.

III. RATIONALE

Neuroendocrine responses, indirectly assessed through urinanalysis, have frequently been used to reflect the human stress incident to flight training. Catecholamine excretion is of interest because it provides an accurate index of stress and because epinephrine and norepinephrine hold physiological and behavioral significance for learning and performance (Frankenhaeuser, 1975).

Low to moderate levels of epinephrine and norepinephrine excretion are related to performance in a positive manner (Frankenhaeuser, 1971). At high levels of stress, the linear relationship may still hold for norepinephrine (Frankenhaeuser & Patkai, 1964), but may be inversely related for epinephrine (Frankenhaeuser, 1971). Moderate levels of stress appear to accompany the most effective learning; therefore, it would seem that training procedures which could moderate stress would be beneficial in pilot training. Further information regarding the stress-learning milieu of T-37 flight training could lead to stress manipulation and management with the purpose of improving undergraduate pilot training.

IV. OBJECTIVES

The present investigation represents a multifaceted attempt to further describe, via urine catecholamine excretion, the stress phenomenon as it relates to flying training. The study was designed to provide information about five specific questions raised by previous research. These questions, significant to the understanding of the role of stress in pilot training, were as follows:

(1) Does high realism simulation result in a measurable stress response?

(2) Does previous airborne flight experience alter one's stress response during simulated flight in the Advanced Simulator for Pilot Training (ASPT)?

(3) Does task-specific high realism simulation prior to exposure to a stressful in-flight lesson unit influence stress or learning in the T-37 aircraft?

(4) Does task-specific high realism simulation prior to exposure to high stress airborne sorties differentially influence T-37 stress of superior and inferior student pilots within the successful range?

(5) Is there a relationship between student and instructor pilot (IP) stress during high-stress lesson units in the aircraft?

It was felt that answers to these questions would help to further describe the role of stress in altering learning and performance in undergraduate pilot training. More effective and efficient learning is the ultimate goal of the research program.

V. METHODOLOGY

The subjects were 32 USAF T-37 pilot training volunteers and 31 IPs. Informed consent was obtained and the research was conducted in accordance with the principles embodied in the Declaration of Helsinki.

The students' normal training regime was maintained except for the scheduling adjustments required by the research design. These adjustments included four ASPT orientation (ASPT-OR) rides and two ASPT spin scenario (ASPT-SPIN) rides for the students. The IPs also remained on a normal schedule except for two ASPT rides.

The students flew four ASPT-OR rides, which served two purposes. The first purpose was to provide a criterion for the assignment of subjects into groups. On each ride, the same five maneuvers (take-off, 60° turns, slow flight, straight-in approach, and landings) were scored automatically with respect to time on target (within preprogrammed tolerances). The subjects were then rated according to their performance on the four orientation rides and systematically matched; subjects from each matched pair were then randomly assigned, one to the control group and one to the experimental group. The second reason for requiring all subjects to perform four orientation rides was to provide assurance that the mere exposure to the ASPT, rather than the content of the ASPT-SPIN, would not be responsible for elevated catecholamine levels should they be found.

Because the ASPT system time was limited, the IP subjects did not receive the orientation. It was felt that because of their considerable experience, the novelty of the simulation would not result in elevated catecholamine excretion levels.

One student group (control) flew four ASPT-OR rides, flew the power-on stall and spin recovery (AIR-SPIN) series in the aircraft, and then flew two ASPT-SPIN rides. A second group (experimental) flew four ASPT-OR rides, flew two ASPT-SPIN rides and then flew the AIR-SPIN rides in the aircraft. The AIR-SPIN ride is the C2201 lesson unit as described

in the T-37 Undergraduate Pilot Training (UPT) Syllabus (Air Training Command, 1975).

The first ASPT-SPIN lasted approximately 45 minutes and consisted of the following elements:

(1) 5 minutes of flying (slow turns, etc.)

(2) demonstration and practice of traffic pattern stalls

(3) demonstration and practice of power-on stalls (two student trials)

(4) demonstration and practice of spin prevention, low left entry (three student trials)

(5) demonstration and practice of spin recovery, low left entry (six student trials)

The second ASPT-SPIN lasted approximately 35 minutes and consisted of the following elements:

(1) 5 minutes of flying (slow turns, etc.)

(2) practice of traffic pattern stalls

(3) practice of power-on stalls (two student trials)

(4) practice of spin prevention, low left entry (three student trials)

(5) demonstration and practice of spin recovery, low right entry (three student trials)

(6) practice of spin recovery, low left entry (three student trials)

The IPs included in this experiment were selected because each happened to be an instructor for one of the students being studied. Data from the IPs were collected on the aircraft sortie in which his student flew the AIR-SPIN ride. Thirteen of the IPs also flew two ASPT-SPIN rides identical to the one flown by students prior to the AIR-SPIN ride. The IPs had not participated in spin practice for approximately 6 weeks.

Baseline excretion data (BASAL) for the students and IPs were gathered on 2 non-flying days. Periods of relative inactivity were selected to avoid academic, physical training, and flight simulator requirements so as to involve low-stress conditions. All collections (BASAL, ASPT-SPIN, AIR-SPIN) were scheduled as close to midday as

possible, so as to control for diurnal variation in catecholamine excretion.

Immediately prior to all timed collections, the subjects emptied their bladders, and were then encouraged to drink at least 200 ml of water each, thereby reducing possible errors due to inadequate amounts of urine from voluntary bladder emptying. The AIR-SPIN collection covered a period lasting from 30 minutes prior to take-off until return to the flightline following the flights. The exact length was noted and recorded.

Each specimen was then stabilized and refrigerated. All specimens were analyzed for free epinephrine and norepinephrine within 48 hours of collection using the Bio-Rad Laboratories (1975) resin column isolation technique. Standard solutions of epinephrine and norepinephrine and aliquots of standard pools were included as a check of validity. Duplicate determinations were calculated as a check of reliability.

Excretion data for the experimental student group consisted of two BASAL, one ASPT-OR, one AIR-SPIN and two ASPT-SPIN rides. The IPs were monitored on two BASAL, two ASPT-SPIN, and one AIR-SPIN (the one flown by their students) rides.

A comparison of the BASAL and ASPT-SPIN rides allowed a decision to be reached for the first research question, that is, whether high realism simulation results in a significant stress response. The influence that flying experience has on the ASPT stress response was approached in two ways. First, IP and student stress responses were compared. Second, data from the ASPT-SPIN rides for the experimental and control groups were compared. Comparison of the experimental and control groups was used to answer question number three, concerning the influence of high realism task specific simulation on inflight stress and learning. Comparisons of students placed into superior (upper half) and inferior (lower half) groups served to answer questions about the interaction of simulation stress and ability level. Pearson product moment correlation was utilized to determine the relationship between student and IP stress on the AIR-SPIN, which was the fifth and final research question.

VI. RESULTS AND DISCUSSION

Of the original 32 student subjects, only 20 adequately completed all phases of the study. Two of the subjects were eliminated from pilot training. Seven subjects were dropped because their training deviated from either syllabus (Air Training Command, 1975) guidelines or experimental protocol. Three additional subjects provided extremely small urine sample volumes, which are known to adversely affect validity, and were therefore dropped from the study.

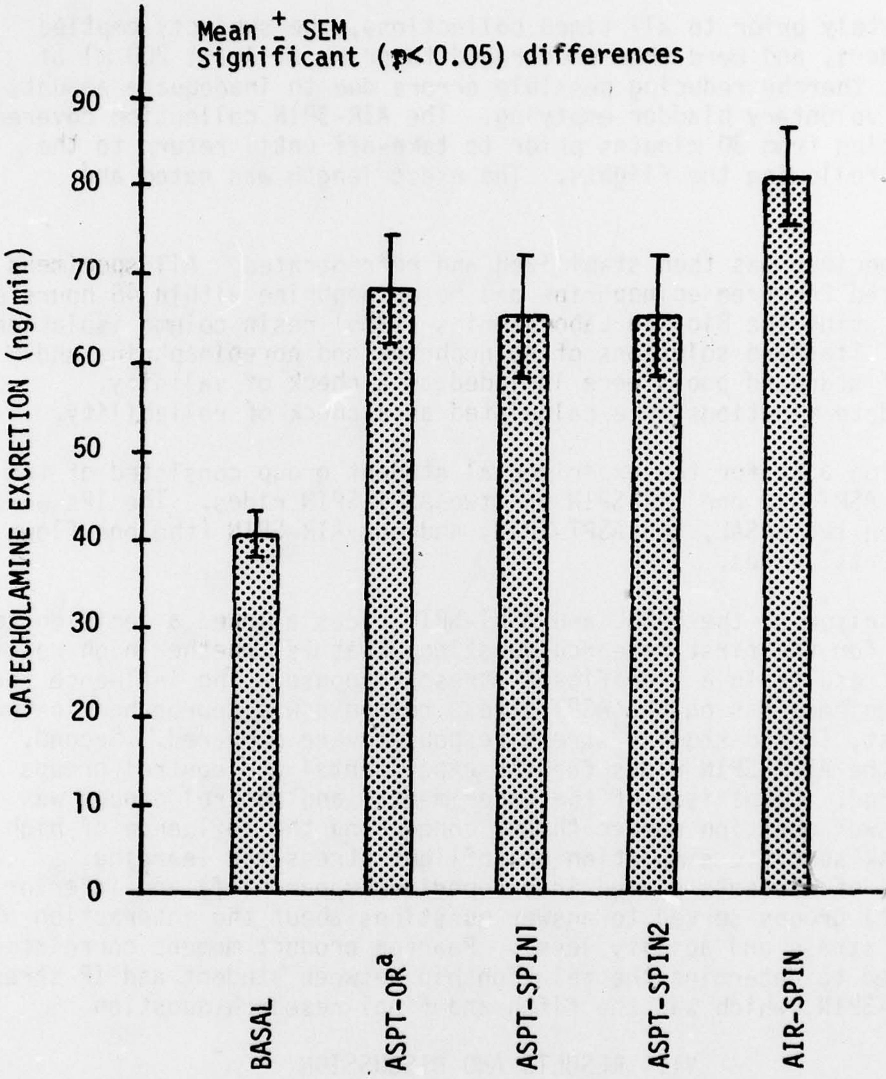

FIGURE 1. Catecholamine Excretion of Undergraduate Pilot Training Students (n=20).

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[a]Shown for comparison only(n = 7).

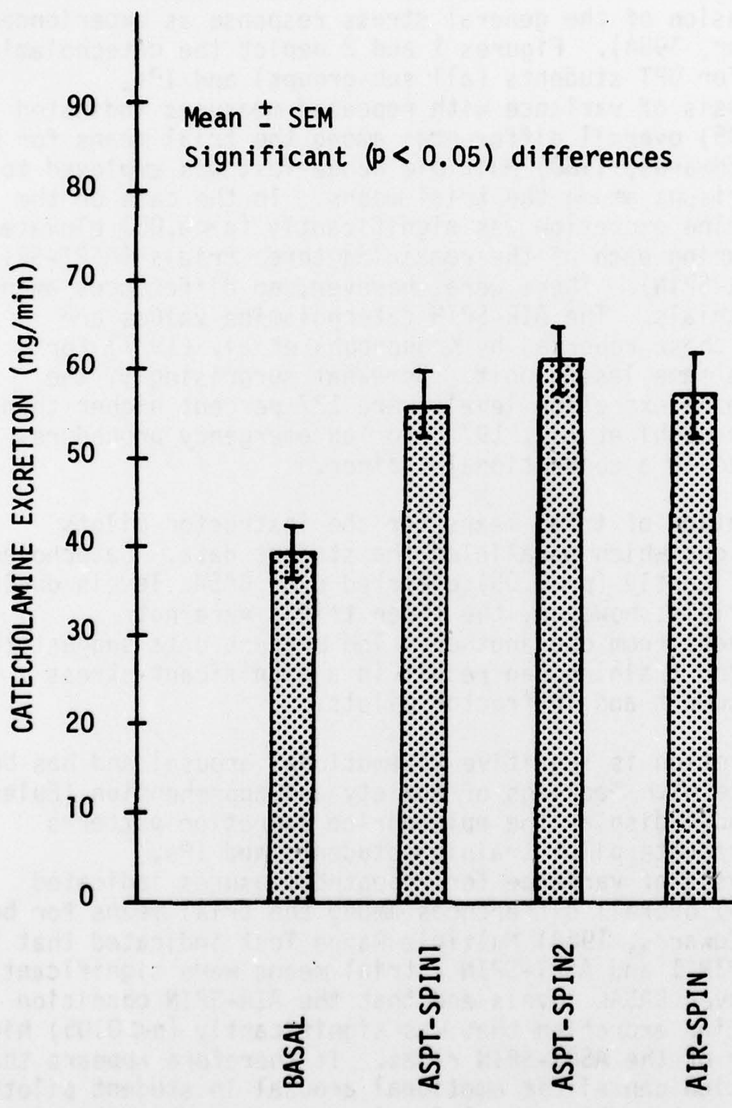

FIGURE 2. Catecholamine Excretion of Undergraduate Pilot Training Instructor Pilots (n=13).

Of the original 31 IPs chosen for study, data were collected on 28. Complete data for all experimental conditions (BASAL, ASPT-SPIN 1, ASPT-SPIN 2 and AIR-SPIN) were available for only 13 instructors. AIR-SPIN student/instructor observations were secured for 18 pairs.

Catecholamine excretion is believed to be a quantifiable physiological expression of the general stress response as experienced by the individual (Euler, 1964). Figures 1 and 2 depict the catecholamine excretion patterns for UPT students (all sub-groups) and IPs, respectively. Analysis of variance with repeated measures indicated siginificant ($p<0.05$) overall differences among the trial means for both groups. Duncan's (Edwards, 1968) Multiple Range Test was employed to make multiple comparisons among the trial means. In the case of the students, catecholamine excretion was significantly ($p<0.05$) elevated over BASAL levels during each of the remaining three trials (ASPT-SPIN 1, ASPT-SPIN 2, and AIR-SPIN). There were, however, no differences among these latter three trials. The AIR-SPIN catecholamine values are slightly lower than those reported by Krahenbuhl et al. (1977) for another group on the same lesson unit. Somewhat surprisingly, the ASPT-SPIN catecholamine excretion levels were 127 percent higher than those reported (Krahenbuhl et al., 1977) for an emergency procedures lesson unit performed in a conventional trainer.

Post hoc examination of trial means for the instructor pilots resulted in conclusions which paralleled the student data. Catecholamine excretion was significantly ($p<0.05$) elevated over BASAL levels during each of the other trials; however, the three trials were not significantly different from one another. The present data suggest that high realism simulator training can result in a significant stress response for both student and instructor pilots.

Epinephrine excretion is sensitive to emotional arousal and has been reported to correlate with feelings of anxiety and apprehension (Euler, 1964). Figures 3 and 4 display the epinephrine excretion patterns observed for undergraduate pilot training students and IPs, respectively. Analysis of variance for repeated measures indicated significant ($p<0.05$) overall differences among the trial means for both groups. Duncan's (Edwards, 1968) Multiple Range Test indicated that for students the ASPT-SPIN 1 and ASPT-SPIN 2 trial means were significantly ($p<0.05$) elevated over BASAL levels and that the AIR-SPIN condition resulted in epinephrine excretion that was significantly ($p<0.05$) higher than BASAL or either of the ASPT-SPIN rides. It therefore appears that high realism simulation can elicit emotional arousal in student pilots, although it does not match the arousal levels experienced in the aircraft.

A *post hoc* comparison of trial means for instructor pilots resulted in conclusions slightly different from those drawn for the students. Epinephrine excretion was significantly ($p<0.05$) elevated over BASAL levels during each of the other three experimental conditions (ASPT-SPIN

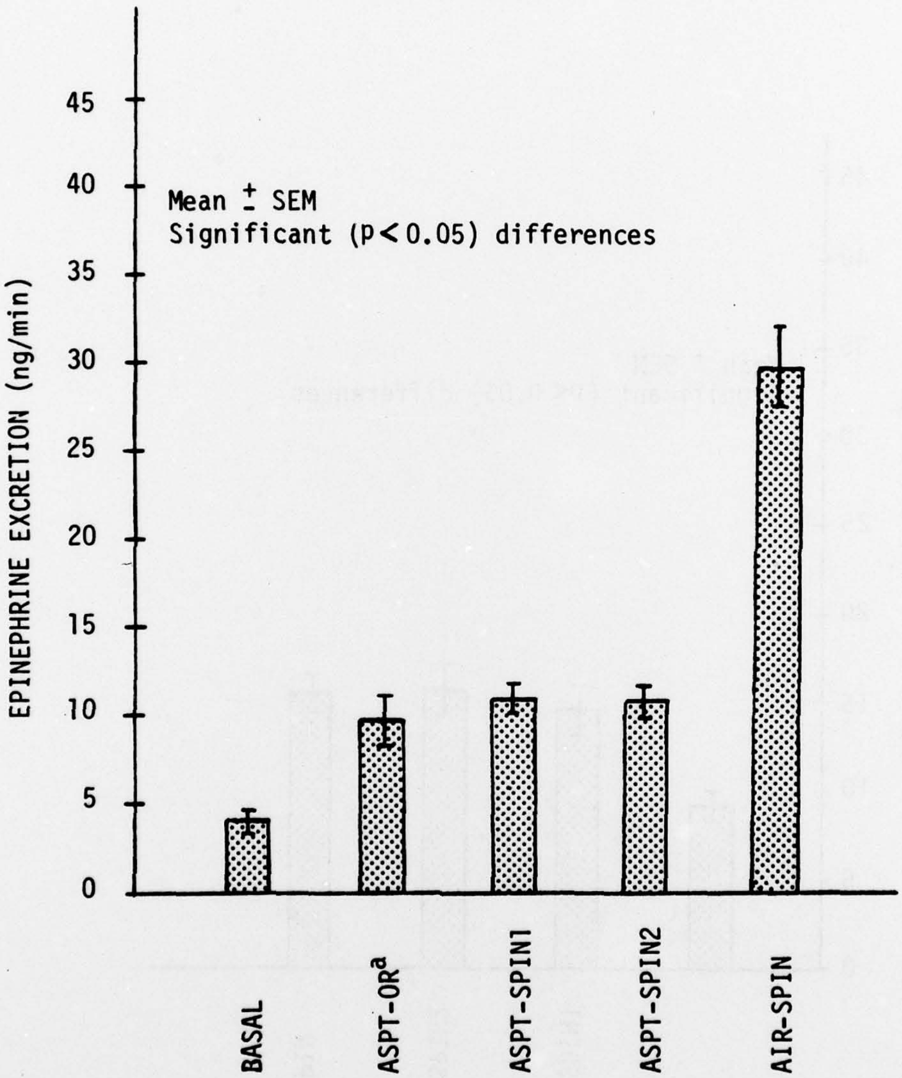

FIGURE 3. Epinephrine Excretion of Undergraduate Pilot Training Students (n=20).

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[a]Shown for comparison only(n = 7).

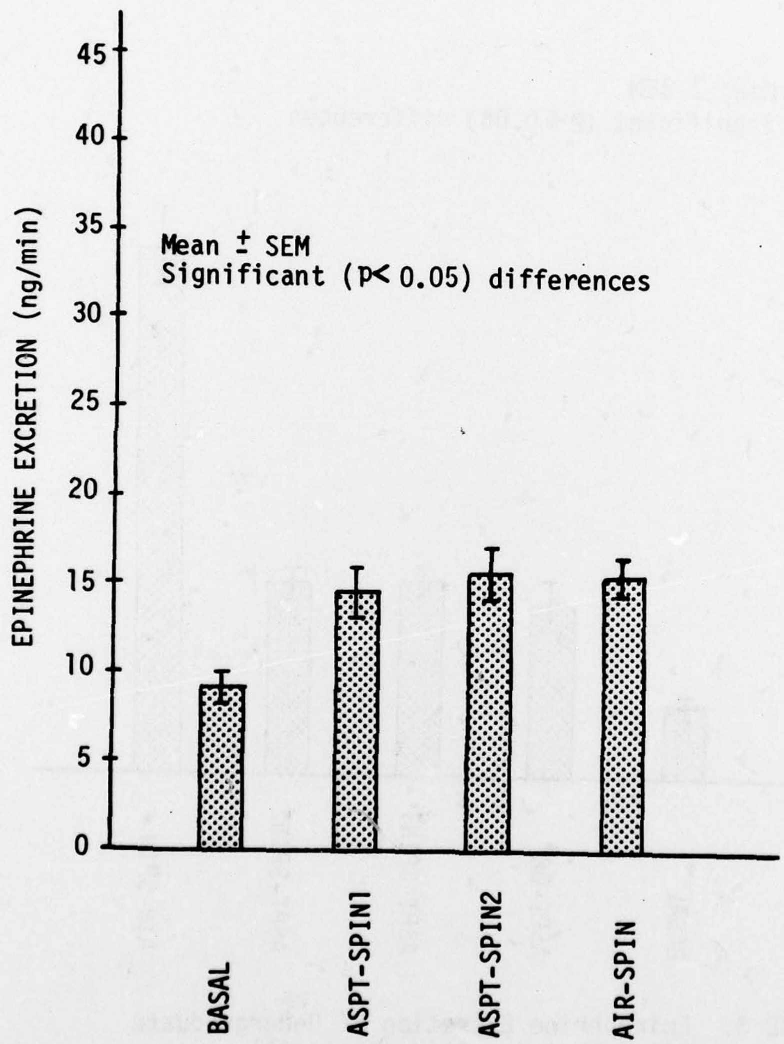

FIGURE 4. Epinenhrine Excretion of Undergraduate Pilot Training Instructor Pilots (n=13).

1, ASPT-SPIN 2 and AIR-SPIN); however, these three latter conditions did not differ from one another. Thus, for instructor pilots, it must be concluded that high realism simulation and aircraft flight of the nature employed in undergraduate pilot training results in emotional arousal which is significantly elevated over BASAL levels; however, there is no significant difference in emotional arousal between sorties from a high realism simulator and the aircraft.

TABLE 1

Comparison of Undergraduate Pilot Training Students and Instructor Pilots (Mean $\pm$ SEM)

Condition/Variable	UPT Student (n=20)	Instructor Pilots (n=13)	F
ASPT-SPIN 1			
Epinephrine (ng/min)	11.9 $\pm$ 1.9	14.3 $\pm$ 3.2	0.467
Norepinephrine (ng/min)	53.4 $\pm$ 6.8	41.6 $\pm$ 3.1	1.747
Catecholamine (ng/min)	65.3 $\pm$ 7.6	55.9 $\pm$ 4.6	0.854
ASPT-SPIN 2			
Epinephrine (ng/min)	11.7 $\pm$ 1.9	16.6 $\pm$ 3.4	1.871
Norepinephrine (ng/min)	53.4 $\pm$ 6.2	45.2 $\pm$ 3.2	1.013
Catecholamine (ng/min)	65.1 $\pm$ 7.6	61.8 $\pm$ 4.4	0.103
AIR-SPIN			
Epinephrine (ng/min)	29.3 $\pm$ 4.7	16.2 $\pm$ 2.4	4.56[a]
Norepinephrine (ng/min)	51.3 $\pm$ 4.8	40.7 $\pm$ 4.5	2.31
Catecholamine (ng/min)	80.6 $\pm$ 6.4	56.9 $\pm$ 5.9	6.58[a]

[a]Significant ($p<0.05$) differences.

A comparison of the excretion data for UPT students and IPs is presented in Table 1. There was no significant difference in the stress response between the groups (students-experimental and control, and instructor) upon either of the ASPT-SPIN rides. There were, however, significant ($p < 0.05$) differences between students and instructors for both epinephrine and total catecholamine on the AIR-SPIN condition. Thus, in the current experiment performance on the power-on stall and spin recovery in the ASPT resulted in arousal and stress responses which were similar for students and instructors, while the AIR-SPIN was much more arousing and stressful for the students. It may be that total flying experience in the aircraft reduces the stress of the AIR-SPIN sortie. An alternative explanation is that both the students and the instructors performed in the role of a student during the ASPT rides, however, the students and instructors participated in their designated roles during the AIR-SPIN sortie. It is possible, albeit speculation, that the student role is more stressful than is the role of the instructor. Additionally (as mentioned previously) the IPs were not given the ASPT orientation rides, and some had never been in a comparable simulator. It may be that the novelty of the experience is somewhat reflected in these data. An obvious difference between simulator training and aircraft training is that simulation is frequently performed in the presence of a number of observers with access to considerable information regarding performance quality. It is therefore possible that some performance anxiety is reflected in the excretion levels, especially in the IPs with little simulator experience.

In an attempt to further explore the significance of flying experience on the AIR-SPIN stress response, various indices of experience were correlated with instructor pilot AIR-SPIN stress. Complete information for these correlations was available for 26 of the instructor pilots. Coefficients of +0.007, -0.083, and -0.028 were found between AIR-SPIN catecholamine excretion and (1) total hours flying time, (2) total hours of T-37 time, and (3) months as an instructor pilot, respectively. None of the correlations was statistically significant. This lack of relationship between stress response on the AIR-SPIN and total flying experience may seem somewhat surprising. It should be noted, however, that AIR-SPIN catecholamine excretion levels for IPs were no higher for the AIR-SPIN than they were for the ASPT-SPIN. Perhaps this explains why no pattern was found. It is also possible that among experienced pilots the stress response to training sorties is determined more by the their personality traits than by their experience. Regardless what the explanation might be, it was concluded that flying experience is not a significant factor in the stress response of IPs.

Another comparison of interest in this investigation was the relationship between instructor pilot stress and student stress and performance. A correlation coefficient of +0.253 was found between student and instructor catecholamine excretion for the 18 student/ instructor pairs for whom complete data were available. This coefficient is not statistically significant.

A significant ($p<0.05$) negative correlation of -0.436 was found to exist between instructor pilot catecholamine excretion and student performance on the AIR-SPIN ride, as reflected by the student's assigned grade. Therefore, poor student performance was accompanied by high instructor stress, and good student performance was accompanied by low instructor stress.

One of the primary contrasts of interest in the current study was the comparison of AIR-SPIN stress responses of students who received ASPT-SPIN experience prior to the AIR-SPIN (experimental) and students who did not receive this treatment (control).

Table 2 displays the descriptive and inferential values of the control (n=10) and experimental (n=10) groups. There were no significant differences between the experimental and control groups on any of the BASAL measures. The most interesting feature provided by the BASAL data is the relatively high norepinephrine means for both groups. Norepinephrine excretion is generally elevated by physical (6) and mental (13) work. Since physical activity was at a minimum during the BASAL collections, it was concluded that the time periods selected for the BASAL measurements included a significant amount of cognition by the subjects. The AIR-SPIN catecholamine excretion means for the experimental and control groups did not differ significantly. It was therefore concluded that ASPT practice on power-on stall and spin recovery items did not reduce the total stress experienced by subjects on their initial SPIN ride on the T-37 aircraft.

High levels of epinephrine have been shown to accompany mental excitement (6), confusion (8), and tremor (15), all of which indicate a lack of control and could adversely affect piloting abilities. Norepinephrine excretion has been shown to rise with physical efforts where events are under the control of the subject (13). The fractional amounts of epinephrine and norepinephrine for the experimental and control subjects (Table 2) on the AIR-SPIN demonstrate different excretion patterns for the two groups. The control group's mean for epinephrine excretion during the AIR-SPIN condition was 91 percent higher than the experimental group's mean. Conversely, the experimental group's mean for norepinephrine excretion during the AIR-SPIN condition was 34 percent higher than the control group's mean. The difference between groups was statistically significant at the conventional $p<.05$ for epinephrine excretion, and a $p<.12$ was observed for norepinephrine excretion. When a ratio was created by dividing norepinephrine by epinephrine excretion, group differences on this ratio were significant at the .01 level of confidence. Thus, it appears that ASPT exposure and practice on power-on stalls and spin recoveries result in a stress response of a somewhat different nature in that a lower level of emotional arousal and a greater amount of mental work are experienced.

TABLE 2

Comparison of Experimental and Control Groups

Condition/Variable	Experimental (n=10)	Control (n=10)	F
BASAL			
Epinephrine (ng/min)	4.4 ± 0.7	3.8 ± 0.6	0.438
Norepinephrine (ng/min)	37.6 ± 4.5	34.8 ± 3.9	0.219
Catecholamine (ng/min)	42.0 ± 4.7	38.6 ± 3.7	0.319
NE/E Ratio	10.6 ± 2.2	11.9 ± 2.4	0.182
ASPT-SPIN 1[d]			
Epinephrine (ng/min)	11.6 ± 2.3	12.2 ± 3.0	0.026
Norepinephrine (ng/min)	52.7 ± 5.1	54.1 ± 9.8	0.009
Catecholamine (ng/min)	64.3 ± 6.3	66.3 ± 9.9	0.016
NE/E Ratio	5.8 ± 0.9	7.9 ± 2.7	0.589
ASPT-SPIN 2[d]			
Epinephrine (ng/min)	10.2 ± 1.9	13.1 ± 3.3	0.567
Norepinephrine (ng/min)	51.9 ± 6.7	54.9 ± 9.4	0.057
Catecholamine (ng/min)	62.1 ± 7.8	68.0 ± 9.7	0.147
NE/E Ratio	8.7 ± 3.6	7.1 ± 1.7	0.154
AIR-SPIN			
Epinephrine (ng/min)	20.2 ± 3.2	38.4 ± 8.0	4.463[a]
Norepinephrine (ng/min)	58.7 ± 6.8	43.9 ± 6.2	2.612
Catecholamine (ng/min)	78.9 ± 8.7	82.3 ± 9.7	0.066
NE/E Ratio	3.4 ± 0.5	1.5 ± 0.3	10.848[b]
C2201 Score[c]	29.8 ± 0.9	29.4 ± 1.2	0.067

[a]Significant ($p < 0.05$) F Ratio.
[b]Significant ($p < 0.01$) F Ratio.

[c]Performance score on the C2201 Lesson Unit (Air Training Command, 1975) Power-on stall and spin recovery series in the T-37 aircraft.

[d]The experimental group performed these sorties prior to the AIR-SPIN lessonwork; the control group performed them following the series.

In spite of the difference in catecholamine excretion, there were no significant differences in the mean performance scores of the experimental and control groups (C2201 lesson unit). It appears that although stress responses were altered by the task-specific pre-training, the acquisition of skill (as demonstrated by performance) was not affected by the experimental treatment.

An interesting final comparison from Table 2 is that of excretion values on the two ASPT-SPIN rides for experimental and control groups. Since the experimental group performed these sorties prior to the AIR-SPIN ride, while the control group performed them following the completion of the AIR-SPIN series, it was felt that this comparison would indicate the influence of specific related aircraft experience on stress responses which accompany simulator training. None of the comparisons was statistically significant. This indicates that the ASPT-SPIN scenario employed in this study or the high fidelity simulation resulted in a significant increase in stress (see Figure 1) and that the stress response is not modified by related aircraft experience. This result is consistent with the aforementioned lack of relationship between flying experience and ASPT stress in IPs.

An earlier study regarding stress in T-37 pilot training (Krahenbuhl et al., 1977) reported differences in the stress response between students of superior and inferior ability. Therefore, the students in the present study were placed into two superior and two inferior groups using the same scores used to match subjects prior to their random assignment into experimental and control groups. A graphic illustration of the AIR-SPIN stress response of the experimental and control groups is provided in Figure 5. Epinephrine excretion levels were similar for the experimental-superior, experimental-inferior and control-superior groups; however, the control-inferior group evidenced an excretion rate approximately double that of the other groups. A similar, but less pronounced difference was noted for catecholamine excretion. These data suggest the possibility that the ASPT experimental treatment helped reduce emotional arousal and stress in inferior subjects, but had little influence on the superior subjects.

VII. CONCLUSIONS

The present study represented a multifaceted attempt to describe, via catecholamine excretion, stress as it relates to flying training. Data were collected during daily activities (BASAL), during sorties performed in high realism simulators, and during actual flight. The following conclusions were drawn:

(1) High realism simulation results in a measurable stress response.

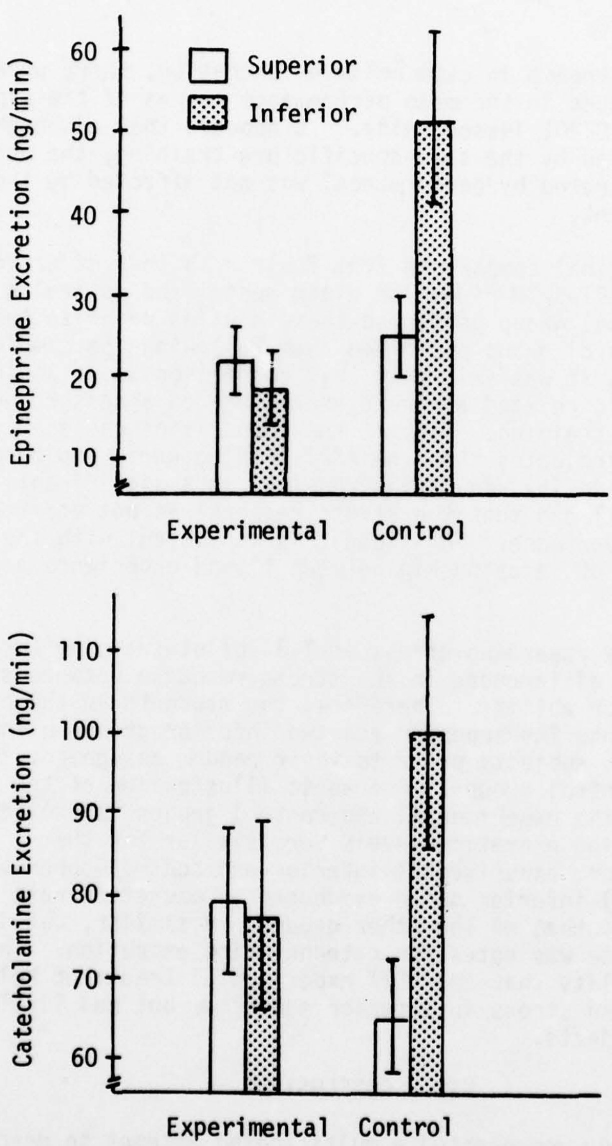

FIGURE 5. Epinephrine (above) and Catecholamine (below) Excretion of Superior and Inferior Undergraduate Pilot Training Students During the AIR-SPIN Lesson Unit (Mean ± SEM).

(2) The ASPT stress response was similar in students and in instructors and was not related to flight experience.

(3) Aircraft exposure to the power-on stall and spin recovery did not alter the stress response of the students attempting a similar maneuver in a high realism simulator. The stress response must be explained by the realism of the simulator and/or the scenario used in this experiment. Less realistic simulators have failed to evoke a stress response, and novelty does not provide a plausible explanation for the simulator associated stress since the experimental design provided control for this problem.

(4) Task-specific high realism simulation prior to exposure to related stressful inflight tasks results in an altered stress response compared to that found in groups not receiving this treatment. Student pilots who received simulation pretraining experienced lower arousal and greater mental activity during stressful in-flight lesson units than did control subjects. A comparison of superior and inferior students within each group, however, suggested that the simulation had the greatest effect on the inferior students.

(5) There was no relationship between student and instructor stress during the power-on stall and spin recovery lesson unit in T-37 pilot training. There was, however, a significant negative relationship between student performance and instructor stress.

Interpretation of the data from this investigation suggests that the ASPT provides a learning environment which is capable of producing a moderate stress response. The character of this response across various training program elements and its significance to undergraduate pilot training remain to be explored.

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